चौंतीसवां दीक्षांत समारोह
THIRTY—FOURTH CONVOCATION

भारतीय कृषि अनुसंधान संस्थान

के निदेशक, अधिष्ठाता एवं स्नातकोत्तर संकाय के सदस्यगण आपको

चौंतीसवें दीक्षांत समारोह

के अवसर पर संस्थान के सभा—भवन के प्रांगण में

शुक्रवार, 9 फरवरी 1996 पूर्वाह्न 11.00 बजे

सादर आमंत्रित करते हैं।

मुख्य अतिथि

नोबेल पुरस्कार विजेता डॉ. नॉरमन ई. बोरलॉग

इस अवसर पर दीक्षांत भाषण देंगे ।

उत्तराकांक्षी
कुलसचिव (शैक्षणिक)
भा.कृ.अ.सं., नई दिल्ली—110012
दूरभाष : 5782817, 5783725

The Director, Dean and Members of the Post Graduate Faculty of the

INDIAN AGRICULTURAL RESEARCH INSTITUTE, NEW DELHI

request your presence at

THE THIRTY-FOURTH CONVOCATION

to be held on Friday, the 9th February, 1996 at 11.00 A.M.

on the grounds of the Institute Auditorium

The Chief Guest

Nobel Laureate Dr. Norman E. Borlaug

will deliver the convocation Address

R.S.V.P.
Registrar (Academic)
IARI, New Delhi-110012.
Phones : 5782817, 5783725

कार्यक्रम

पूर्वाह्न 10.55 * दीक्षांत मंडल का पंडाल में प्रवेश

पूर्वाह्न 11.00 * निदेशक द्वारा दीक्षांत समारोह के शुभारंभ की घोषणा

* वन्दना
* निदेशक द्वारा स्वागत भाषण
* अधिष्ठाता द्वारा रिपोर्ट की प्रस्तुति
* उपाधियों के लिये अभ्यर्थियों की प्रस्तुति
* अनुपस्थित अभ्यर्थियों की उपाधि–स्वीकृति
* श्रेष्ठता पदकों की प्रस्तुति
* संकाय पुरस्कारों की प्रस्तुति
* स्मारक पुरस्कार की प्रस्तुति
* भा.कृ.अ.सं. के प्रकाशनों का विमोचन
* भा.कृ.अ.सं. में विकसित फसलों की किस्मों का विमोचन
* मुख्य अतिथि द्वारा दीक्षांत भाषण
* निदेशक द्वारा दीक्षांत समारोह के समापन की घोषणा
* राष्ट्रगान
* दीक्षांत मंडल का पंडाल से प्रस्थान

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* यह निमंत्रण पत्र केवल आपके लिए है। कृपया इसे साथ लाएं और कार्यक्रम आरंभ होने से 30 मिनट पूर्व स्थान ग्रहण कर लें।
* कृपया हैंडबैग, ब्रीफकेस या कैमरा साथ न लाएं।

PROGRAMME

10.55 A.M. * Entry of the Convocation procession in the *Pandal*

11.00 A.M. * Director declares the Convocation open

* Invocation
* Welcome address by the Director
* Report by the Dean
* Presentation of the candidates for the award of degrees
* Admission to the degrees *in absentia*
* Presentation of merit medals
* Presentation of Faculty Awards
* Presentation of memorial Award
* Release of IARI publications.
* Release of IARI varieties
* Convocation address by the Chief Guest
* Director declares the Convocation closed
* National Anthem
* Convocation procession leaves the *pandal*

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* This invitation is exclusively for you. Please bring the card with you and be seated 30 minutes before the programme.
* Please do not bring handbag, briefcase or camera.

34th Convocation

Indian Agricultural Research Institute

February 9, 1996

Convocation Address

by

Dr. Norman E. Borlaug

NEW DELHI

THE GREEN REVOLUTION
PAST SUCCESS AND FUTURE CHALLENGES

by

Norman E. Borlaug

CIMMYT*

Minister of Agriculture, Dr. Jagannath Mishra, Hon'ble Minister of State Capt. Ayub Khan, Dr. R.S. Paroda, Director General, ICAR, Dr. R.B. Singh, Director, IARI, Dr. Anupam Verma, Dean, Post-Graduate School, IARI, Ex-Directors of IARI, Dr. A.B. Joshi and Dr. H.K. Jain, Dr. Tinothy Reeves, Director General, CIMMYT, distinguished members of the Academic Council, members of the Management Committee, guests, dear students, ladies and gentlemen:

Introduction

I feel honored to have been invited to participate in this Convocation ceremony of the Post-Graduate School of the Indian Agricultural Research Institute and to address this distinguished gathering, especially the graduating students and their proud parents.

It is a pleasure to once again visit India. As I stand before you, my memory flashes back to my first visit in India in 1960 as a member of a team of FAO and Rockefeller Foundation scientists who were studying the status of wheat research and production problems in North Africa, and the Middle and Near-East countries—from Morocco to India.

It was from this survey, that a "hands-on" training program was established in Mexico in the, Mexican Government-Rockefeller Foundation Office of Special Studies, which is the predecessor organization to the International Maize and Wheat Improvement Center, (CIMMYT), and also where the idea was born to establish an international spring wheat yield nursery cooperatively with all of the nations in this region to build—and freely exchange—a stock of superior wheat germplasm with broad adaptation and resistance to diseases.

*also President SASAKAWA AFRICA ASSOCIATION

My next visit was in 1963, when I was invited by Dr. B.P. Pal, Director of Indian Council of Agricultural Research (ICAR) at the suggestion of Dr. A.B. Joshi, the Director of the Indian Agricultural Research Institute (IARI), and Dr. M.S. Swaminathan, then Head of the Botany Division of the same institution. My charge was to see whether some of the newer Mexican wheats which had come to Swaminathan by way of the US Department of Agriculture's International Rust Nursery two years before might be of some use to them in their breeding program.

Without going into details, it became evident from that visit, and on my way home to Mexico from stops in Pakistan and Egypt, where a large number of the new wheats had been brought by young scientists from these countries who had come to Mexico for training, that the new semidwarf wheats could play a significant role in helping to increase wheat production in India and many of the other countries in the Near and Middle East.

From 1963 onward, until I retired as leader of the CIMMYT wheat research and production program in 1979, I came to India at least once and some times twice each year, generally during either the planting season or more probably, just preceding the harvest. I established with my many colleagues here a productive working relationship and close personal friendships.

Historical Background

Although many know the story, permit me to briefly recount for the students the events leading up to the tremendous take-off in wheat production in India. At the political level, the key people who made this happen were Minister of Agriculture Shri C. Subramaniam and his very effective permanent secretary, Mr. Sivaraman and, of course, subsequently Prime Minister

Indira Gandhi. At the scientific level, Dr. B.P. Pal, Dr. A.B. Joshi and Dr. M.S. Swaminathan, and many other scientists, including Vice Chancellor of Andhra Pradesh Agricultural University Dr. M.V. Rao, played key roles.

First, a little background. During the late 1950s and early 1960s food deficits in India had been requiring importation of 3 to 4 million tons of grain per year. However, because of a bad monsoon in 1965 and 1966, imports exploded upwardly to 10 million tons, and India was in dire straits. It was during this period that, after three years of testing on experiment stations, the so-called high-yielding Mexican wheat varieties, which had proven very interesting under experimental conditions, where considered as a possible way to break the worsening food deficit. I now fully appreciate the pressures that Shri Subramaniam was under during this period, after reading his book **"The New Strategy in Indian Agriculture, the First Decade and After,"** published in 1979. When he proposed a dramatic change to revitalize the national agricultural research system, and to move forward aggressively to expand food production by using the promising high-yielding Mexican wheat varieties, there were many who were in opposition not only within the research establishment, but also in other branches of the Ministry of Agriculture, other Ministries, and especially in the Planning Commission. This did not, however, dissuade Subramaniam from pushing ahead.

With preliminary data indicating the high yield potential of the Mexican semidwarf wheats, he courageously approved in 1965 the importation of 250 tons of Lerma Rojo 64 and Sonora 64, two of the new Mexican wheat varieties. (300 tons of these varieties also were imported by Pakistan.) Subramaniam encountered great opposition to this importation, especially from V.K.R.V. Rao, Planning Commission member. Many senior scientists were also against the introduction of these new Mexican wheats- partly because of fear and partly because of ego—whereas the younger scientists, who had seen then growing in the field, were very much in favor of dramatic action. Subramaniam got around the bureaucratic barriers put up to stop this importation by indicating that the seed was for on-farm trials and demonstrations, not for commercial sale.

From my side, I also was also experiencing serious difficulties in getting the seed shipped from Mexico. Our whole seed multiplication program for the previous 15 years had been handled by a private farmers' cooperative in Sonora which was highly effective in producing quality seed efficiently. Unfortunately, the Mexican government's seed organization

insisted on handling the wheat seed export, and therein began a series of problems that nearly terminated in the failure of the whole operation. First, there were delays in moving the fleet of about 30 large trucks across the Mexican border and to the port at Los Angeles for loading on the last freighter that would get the seed to Bombay and to Karachi in time for proper planting in mid-October. We had to pay demurrage for holding the freighter for three extra days while we were fighting the bureaucracy to get the fleet of trucks across the international border. Finally cleared, the trucks were held up by the national guard for a day, because a serious racial riot broke out in the Watts neighborhood of Los Angeles and all traffic leading into the city was being blocked or diverted. We eventually arrived at the port on Sunday night and got the seed aboard and shipped out early Monday morning. Unfortunately, 12 hours later, war broke out between India and Pakistan. In Singapore, the seed was divided and placed in two ships, which arrived in Bombay and Karachi six weeks later than we anticipated. We were planting very late and there was no time to test for seed germination. To our dismany five days later we saw that the germination was poor. Even though the seed was very expensive, we doubled seeding rates. Although the stands that emerged were only half of what they should have been, the seedlings tillered beautifully, and we added more fertilizer and water effectively. By early January it was obvious that the crop would be good.

Then, I received terrifying calls from someone in Delhi saying that the Mexican wheats were being attacked severely by stem rust, I hastened to obtain passage on the first airline to India. However, Dr. Harrar, President of the Rockefeller Foundation, told me not to go since I was too personally involved. Rather, he decided to send two other scientists to inspect the reported damage: Dr. Joe Ruppert, a Rockefeller Foundation employee and close friend and associate, and Dr. Harry Young, a wheat pathologist from Oklahoma State University. They traveled widely throughout the area where the Mexican wheats were growing and found no evidence of any rust. However, they did find heavy rust on one of two local Indian varieties. It appeared that "political factors" were involved in this initial unfavourable report.

Unannounced, Mr. V.K.R.V. Rao showed up in Ciudad Obregon, Sonora, Mexico, in March 1966, and said he wanted to learn more about our wheat research program. The first day we reviewed the program, the second day we visited farmers growing the new semidwarf wheats, the third day we visited the irrigation commission and farmers' seed cooperatives, the fourth day he left for India. I didn't know until months later that he was trying to make sure no errors were being made in the introduction of these huge commercial quantities of seed.

It was under these still uncertain conditions that Minister Subramaniam made a very courageous and historic decision in early 1966 to import 18,000 tons of Lerma Rojo seed from Mexico, against the advice of most of his senior scientists. This was, by far, the largest import of seed in world history. It unleashed a flood of criticism from many academicians in ivory halls around the world. Sri Subramaniam and I were charged, by some critics, with recklessly playing with the lives of million of people.

For the 1966-67 season, approximately 240,000 ha were planted to the seed of Mexico varieties. When I visited India in March of 1967, everywhere Dr. Swaminathan, the late Dr. R. Glenn Anderson of the Rockefeller Foundation, and I traveled, we encountered tremendous enthusiasm—indeed euphoria—among all farmers—large and small—for the new wheat varieties. When we returned, I reported on this to Mr. Subramaniam, insisting that all that was necessary now was to have assurance of availability of fertilizer, credit to buy the fertilizer at time of planting and pay for it at harvest, and a fair price for the grain at harvest which would approach the price of wheat at international market. Subramaniam held up his arms and said "you've forgotten I can't help you with this because I lost my seat in the Lok Saba in last month's elections and I am out of office at midnight tomorrow, March 31st." This threw a blanket of gloom over out whole program. He insisted that I see Deputy Prime Minister Ashok Metha, Chairman of the Planning Commission, and Minister of Heavy Industry and Petro-Chemicals, before I left India the next day. An appointment was made and Swaminathan and I went to see Ashok Metha at six o'clock in the afternoon on March 31st. This discussion was probably, according to Subramaniam, the most important hour of my scientific life, for it led to changes in policy. It began

very stormily as I talked about the need to dramatically change India's disastrous agricultural policies on fertilizer, credit and grain prices. He was indignant. A flood of loud angry words were emitted by both of us until we both ran out of breath and began to talk in rational tones again.

Ashok Metha bluntly said that India did not have the foreign exchange to expand fertilizer imports greatly, much less invest in large fertilizer manufacturing complexes. I countered by saying that the development of a fertilizer industry, and of the agricultural sector in general, was of a higher order of priority than the large capital investments being made in other sectors, since fertilizer was essential for increasing food production. Moreover, I emphasized it was a risk for India to continue to rely, for a large amount of its essential food, on imports under concessional sale PL 480 contracts from the United States. These types of contracts could be cut off either by unavailability or shortages by the supplier or by shifts in political winds. Ashok Metha knew all too well about the "political winds" of which I spoke, since U.S. President Lyndon Johnson was using food aid to increase the pressure on the Government of India to support the Vietnam policy of his administration.

I left for Mexico four hours after our meeting. Two weeks later, I received a series of clippings from the major New Delhi newspapers, dated April 1st, disclosing that the Government had revalidated all uncompleted contracts for constructing fertilizer factories, which would have been voided, as of midnight March 31st. Moreover, the Government also embarked on a program to greatly increase fertilizer importation in the short-run. These were drastic changes in fertilizer policy.

In October 1967, Prime Minister Indira Gandhi lent her prestige to the wheat campaign by spading-up the flower bed in front of the Prime Minister's residence and planting the new wheats, which developed beautifully. Moreover, at her insistence, all professors in agricultural universities in the wheat belt were expected to plant a wheat demonstration plot employing the new technology in their front yard in January 1968 she released a commemorator postal stamp honoring the wheat revolution—well before there was any evidence of the forthcoming beautiful harvest—clearly indicating her faith in the new technology. By early March, it was evident that the 1968 wheat harvest was going to be enormous.

Impact of the Green Revolution

The term "Green Revolution" was coined in 1968 by Dr. William S. Gaud, Director of the US Agency for International Development (USAID), to describe the breakthrough in food production caused by the introduction and rapid diffusion of the new semidwarf wheat and rice varieties in India, Pakistan and other parts of the developing world.

The Green Revolution has had a far-reaching impact on the economic and social structures of many low-income, food-deficit nations. Many initial reporters chose to depict the Green Revolution as the wholesale transfer of technology from high yield agricultural systems to peasant farmers in the Third World. To me, however, it signified a new era in agricultural research and development in the Third World, one in which modern principles of genetics and plant breeding, agronomy, plant pathology, entomology and economics were applied to develop technologies appropriate to the conditions of local farmers. The impact on food production of the high-yielding wheat and rice technologies has been enormous (Table 1). In 1964-65, there were probably less than 5,000 hectares worldwide planted to the new high-yielding semidwarf wheat and rice varieties worldwide; by 1990, there were more than 130 million hectares growing these plant types.

Table 1. Estimated Changes in Wheat and Rice Production, Yield, Area, and Input Use in Developing Countries, 1965-94

	1965	1975	1980	1985	1994	%Change 1965-94
Population, millions	2,210	2,950	3,280	3,650	4,350	97
Wheat & rice production, million t	303	451	527	652	739	144
Yield, t/ha	1.5	1.8	2.3	2.8	3.2	113
Area, million ha	190	228	234	234	230	21
Fertilizer, million t	4	20	38	46	65	1,525

Source: FAO Production and Fertilizer Yearbooks

The new wheat and rice varieties have been the catalyst for many other technological changes in agriculture in Asia. fertilizer use has increased more than fifteen-fold, the irrigated wheat and rice area has expanded by

50%, and the amount of irrigation water available for wheat and rice cultivation more than doubled. The high-yielding wheat and rice technologies also led to positive spillover effects on other crops, as farmers sought to improve productivity in other farm enterprises.

One of the greatest contributions of the Green Revolution in India has been the land saved, which would have been needed to feed the population. Let's examine the figures briefly. had the same wheat and rice yields prevailed today that prevailed in 1961-65, India would have needed an additional 94 million hectares of similar quantity to produce the 1995 wheat and rice harvests (Tables 2 and 3). Imagine the

Table 2. Profile of Wheat Production in India and Land Saved Through Productivity Gains

YEAR	AREA 1000 ha	YIELD kg/ha	PRODUCTION 1000 ha	LAND SAVED 1000 ha
1961-66	13,191	830	10,950	-
1970	16,626	1,209	20,093	7,582
1975	18,111	1,338	24,235	11,087
1980	21,962	1,437	31,560	16,061
1985	23,100	1,909	44,100	30,032
1990	23,500	2,120	49,850	36,560
1995	25,490	2,560	65,240	53,112

Source: FAO Production Yearbooks

Table 3. Profile Rice Production in India and Land Saved Through Productivity Gains

YEAR	AREA 1000 ha	YIELD kg/ha	PRODUCTION 1000 ha	LAND SAVED 1000 ha
1966-70	36,360	981	35,770	-
1975	37,890	1,045	39,580	2,487
1980	38,970	1,082	42,180	4,027
1985	41,100	1,418	58,300	18,329
1990	42,170	1,756	74,053	33,827
1995	41,640	1,952	81,260	41,194

Source: FAO Production Yearbooks

environmental consequences of trying to bring this additional land into cultivation! Indeed, it would have required the bringing into production lands not suited for intensive cultivation, including forest and grasslands, hillsides.

Contrary to the prediction of some critics—that the new high-yielding technologies were only suitable for richer farmers—it is now well-documented that India's resource-poor farmers, with only relatively brief lag time, adopted the new seed/fertilizer technologies about as frequently as the more resource-privileged, large-scale farmers. Nor did the prediction that Green Revolution technologies would accelerate labor displacement in rural areas prove true. While some categories of labor declined, e.g., threshing, many new job opportunities opened up in farm machinery operations, input supply, grain marketing and other agro-services; the net effect on rural employment has been positive.

The consumer, however, has been the main beneficiary of the Green Revolution. the really important attribute of the new technologies was that they simultaneously provided farmers with increased profits and consumers with more bountiful and reliable food supplies which, in turn, led to declining real food prices. It is calculated that in real terms the cost of wheat-rice has declined by over 70% in this time - a tremendous contribution to poor men, women and children. The larger wheat and rice harvests have enhanced food security in many developing countries. In India, for example, wheat stocks reserves have been built up in good years to help compensate for the bad years when harvests are not as good. Greater food security has been especially important to the poor consumer, who in the past suffered chronic and serious malnutrition in years when poor harvests sent food prices skyrocketing up.

The Green Revolution also taught many political leaders in the Third World that a dynamic agricultural sector can neither be initiated nor sustained without the support of dynamic research and technology delivery systems. Over the past 25 years a large research infrastructure—scientists, experiment stations, laboratories, trained manpower—has been built up in the developing world, involving tens of thousands of researchers, mostly working in publicly funded institutions. Considerable growth in the international agricultural research network has also occurred

since the establishment of IRRI in 1960 and CIMMYT in 1966. Today 16 centers and 1,200 scientists are supported by the Consultative Group for International Agricultural Research (CGIAR).

Current Status of World Food Supply

In 1990 our world food supply totaled about 4.6 billion tons gross weight (2.4 billion tons edible dry matter), which was more than twice the tonnage produced in 1961-65 (Table 4). Approximately 98% of this food supply came from the land; less than 2% came from the oceans and inland waters. Some 30 plant species provided most of the world's calories and protein. Eight species of cereal grains, collectively accounted for 70% of calories and 42% of the protein contained in the world food supply.

Table 4. World Food Production, 1990

Commodity	Million metric tons			Production Increase, % 1980-90[2/]
	Gross Tonnage	Edible Dry Matter[1/]	Protein[1/]	
Cereals	1,970	1,640	165	20
Wheat	600	528	62	29
Maize	480	422	44	13
Rice	520	353	30	31
Barley	180	158	16	10
Sorghum/millet	85	76	7	-4
Roots & Tubers	575	154	10	5
Potato	270	59	6	0
Sweet potato	125	37	2	-7
Cassava	150	55	1	22
Legumes, oilseeds, nuts	300	204	68	29
Sugarcane & sugarbeet[3/]	125	125	0	20
Vegetables & melons	450	53	5	26
Fruits	345	47	2	17
Animal products	850	168	74	24
Milk, meat, eggs	750	141	56	18
Fish	100	26	18	33
All Food	4,615	2,390	397	20

1/ At zero moisture content, excluding inedible hulls and shells.
2/ 1979-81 and 1989-91 averages used to calculate changes.
3/ Sugar content only.
Source: 1990 FAO Production Yearbook

If the world's food supply were distributed evenly the total food supply could have provided an adequate diet (2,350 calories, principally from grain) for 6.5 billion people—1 billion more than the current population. If, however, dietary standards in developing countries had been better, so that 15% of the calories came from animal products, less than 4 billion people could be fed. And if people in developing countries had attempted to obtain 30% of their calories from animal products, as in the USA or European Union countries, a world population of 2.7 billion people could be sustained—only half of those actually present on the planet Earth!!

Feeding the Future: The Challenges Ahead

Future world food demand will be determined by two factors: population growth and per capita food consumption. The United Nations Population Agency's medium projection is for world population to reach 6 billion by the year 2000 and about 8 billion by 2025, before stabilizing at about 10 billion toward the end of the 21st century. Over 90% of the world's projected 3 billion additional people will reside in what are now low-income developing nations (Table 5).

Table 5. World Population Projections

	Population (millions)			% Increase
Region	1990	2000	2025	1990-2025
Low- and Middle-Income Economies				
Sub-Saharan Africa	495	668	1,229	148
East Asia & pacific	1,577	1,818	2,276	44
South Asia	1,148	1,377	1,896	65
Europe	200	217	252	26
Middle East & N. Africa	256	341	615	140
Latin America & Caribbean	433	515	699	61
Sub-total	4,146	4,981	7,032	70
Other Economies[1/]	321	345	355	11
High-Income Economies	816	859	915	12
World	5,284	6,185	8,303	57

1/ This classification includes the former Soviet Union, Cuba, the Democratic people's Republic of Korea, for which inadequate and/or unreliable data is available
Source: World Development Report 1992, World Bank

Even if the often inadequate per capita nutritional levels of 1990 were maintained, annual world food production in 2025 must be 60% greater (7.4 billion tons gross weight) than it was in 1990 (4.6 billion tons gross weight). However, if there are dietary improvements among the poor in low-income, food-deficit countries annual world food demand by 2025 could be as great as 8.2 billion tons, gross weight, twice as much as the 1990 production level.

South Asia and sub-Saharan Africa are the regions with the most poverty (Table 6). By the year 2000, South Asia will still have the largest absolute numbers of poor people although sub-Saharan Africa still will have the highest percentage—50% of the total population—in such dire straits. Hopefully, some of the students in this room will make contributions to the reduction of poverty through their research and work as agricultural professionals.

Table 6. Poverty[1/] in the Developing World, 1985-2000

	Percentage of population below the poverty line			Number of poor (millions)		
Region	1985	1990	2000	1985	1990	2000
South Asia	52	49	37	532	562	511
East Asia	13	11	4	182	169	73
Sub-Saharan Africa	48	48	50	184	216	304
Mideast & N. Africa	31	33	31	60	73	89
eastern Europe[2/]	7	7	6	5	5	4
Lat. Amer. & Carib.	22	26	25	87	108	126
All Developing	31	30	24	1,051	1,113	1,107

1/ US$ 370 annual income per capita in 1985 purchasing power parity is used as the poverty line; it is based on estimates from a number of sources. In 1990, the poverty line would be approximately US$ 420 annual income per capita.

2/ Does not include the former USSR.

Source: World Development Report 1992 (Table 1.1, p. 30)

Using the population growth rates shown above, and expected changes in per capita cereal demand, I have come up with following projections for the cereal crops through the year 2025 (Table 7). to meet the projected

food demands, the average yield of all cereals must be increased by 80% between 1990 and the year 2025. Fortunately, there are still many improved agricultural technologies—already available or well-advanced in the research pipeline, and only partially being exploited—that can be employed in future years to raise crop yields. there are still large unexploited "yield gaps" in virtually all low-income, food-deficit developing countries as well as in the former Soviet Union and Eastern Europe.

Yieldscan still be increased by 50-100% in many areas of Asia, Latin America, the former USSR, and Eastern Europe, and by 100-200 percent in much of sub-Saharan Africa. Such productivity gains can be achieved by improving efficiency all along the crop production line, beginning with better land preparation to assure optimum crop stands, more timely planting of the very best available varieties, proper fertilization, and improved control over menacing weeds, diseases and insects. Of course, as yields become higher, assuring proper nutrient balances and conserving soil moisture under rainfed agriculture, or if under irrigation, better water management, will become ever-more important.

Table 7. Current and Projected World Cereal Production and Demand (million tons) and Yield Requirements (kg/ha)

Production	Current	Projected Demand		Yields, t/ha Actual	Required	
	1990	2000	2025	1990	2000	2025
Wheat	600	740	1,200	2.4	2.8	4.4
Rice	520	640	1,030	2.4	3.1	5.3
Maize	480	620	1,070	3.7	4.1	5.8
Barley	180	220	350	2.3	2.7	4.1
Sorghum/millet	85	110	180	1.5	1.8	2.6
All cereals	1,970	2,450	3,970	2.5	2.9	4.5

Source: FAO Production Yearbook and my estimates

More recent estimates by IFPRI indicate that extra demand for wheat and maize will far outstrip that for rice.

The declining per capita availability of arable cropland in many of these countries means that future production gains must come, even more than

in the recent past, from higher crop yields and more intensive land use practices. Furthermore, because 10 to 12 years usually elapse between the time research is funded to the point when the results show up in food production figures, the productivity gains for the remainder of the 20th century must come from research investments already made. Fortunately, there are many improved technologies already available or well-advanced in the research pipeline that can raise crop yields by 50-100% in most tropical and subtropical farming areas of Asia and Latin America, and by 100-200% in much of sub-Saharan Africa. To capitalize on this unexploited agricultural potential, however, far greater investments will be needed now and in future years in agricultural research, water resource development, input production and distribution systems, rural education, and public health.

The Importance of Agricultural Research

Continuing research and new technology generation are the key to meeting the world food demands of the 21st century. Although the capacity to produce and distribute new agricultural technology in Third World has increased immensely over the past 30 years, the rate of agricultural modernization during the 1980s has slowed. One of the problems, I believe, lies within the organization and management of agricultural research system itself—both at the national and international level. i am especially concerned about the very poor links between research, *per se*, and technology generation and delivery.

In looking back over my 52-year career in international agricultural research and development, I have found it often easier to develop an improved technology than to get it into the hands of farmers. In trying to transform a stagnant traditional low-yielding agriculture, we must be aware of the inertia and defeatism that exists at many levels in government organizations. The peasant farmer is often blamed for being unwilling to adopt new technologies; I strongly disagree with this thesis, having found the peasant farmer to be very receptive to adopting new technology if it offers a large increase in productivity within reasonable levels of risk.

Often the major stumbling block has been government civil servants, including many agricultural research leaders, who try to protect them-

selves by clinging to the *status quo* and thereby often repress creative new research initiatives. For this group, *status quo* of the known traditional methods are comfortable whereas the fear of the new unknown technology is frightening. These are the negative forces against which agricultural researchers and extension workers must struggle if they are to succeed in serving their farming communities. Without venturesome scientists capable of cutting across disciplines and integrating research information into viable technologies, and who have the courage and ability to make their case with political leaders to bring research advances to fruition, the future diffusion of new agricultural innovations in the low-income, food-deficit nations is not at all assure.

From my perspective, agricultural research managers and decision makers need to spend more time on the ground, monitoring what is happening — or not happening. Further, some IARC researchers must limit their pursuit of beautiful academic butterflies and must strengthen their interactions with national research and extension systems, and farmers. Too many have become detached from the realities in farmers' fields, preferring to measure their achievements by the information and products generated — and learned papers published — rather than by adoption of their technologies in the countryside. This should be changed.

Plant breeding is the greatest practical achievement of the biological sciences in the 20th century. Compared to the traditional varieties, today's new cereal crop varieties are vastly more efficient in grain production and in their genetic resistance to diseases and insects and tolerance of various agroclimatic stresses. The greatest successes in diffusing improved cereal varieties have been in wheat and rice, where about 70% of the area of in the developing world is planted to high-yielding varieties. Growing success is also being achieved in diffusing the improved varieties of maize, barley, sorghum, the pulses, and oilseeds developed by agricultural researchers.

Permit to comment on obsolescent plant and animal quarantine regulations. Thirty years ago, the human disease quarantines were complicated and bureaucratic. To travel internationally one had to have a large number of vaccination certificates, for a large number of diseases. Some of these vaccinations, such as for cholera and typhoid, were very

ineffective and not recognized as being useful by many MDs. Nevertheless, a large, flourishing, sterile, difficult bureaucracy was spawned. Over many years of struggle this has been changed, and the result is that today, to travel internationally, one needs only a vaccination certificate for yellow fever, in most countries.

Even though two hundred million tons of grain per year and large tonnages of many other agricultural commodities are traded internationally, there is no fumigation or disinfection required, because of the way the standards are written. Yet there are many impurities that move with this grain, including weed seed, loose bits of straw, dirt, insects, and fungal spores of many different kinds. On the other hand, if one attempts under current regulations to ship 5 to 10 gram samples of grain of improved crop varieties to collaborators in other countries, one is confronted with a whole complex of plant quarantine regulations and an extremely inflexible and arrogant bureaucracy.

At the present time, some scientists in the world are outspokenly attacking others for lack of genetic variation in the improved crop varieties they are developing. I do not accept this accusation. It is my belief, certainly in wheat but I am sure it is true in rice, maize and most of other basic crops, that there is more genetic variation in the total cropping system today than has ever existed in the past. This tremendous genetic variation has been incorporated by conventional plant breeding and in more recent years further improved by the use of biotechnology transformations and the incorporation of DNA from other species and genera. Of course, it is true that not all of that genetic variation is being planted and that some very popular and successful varieties or hybrids are grown on vast areas. However, if plant pathologists and entomologists are properly monitoring commercial crops to report changes in new races, if active plant breeding programs are under way to pyramid genes for resistance, and if seed delivery systems are in place to move the seed of new varieties to farmers' fields, then our agricultural areas can be protected from any serious damage. This is more true today than ever before.

One of the great obstacles to further assist in the diversification of genetic material is the above mentioned difficulties with the plant quarantine system. They are obsolete, they need to be brought up to date

and made realistic as has been done in the human medical field. Why don't agricultural scientists speak out against the ludicrous system of plant quarantine for experimental germplasm? Surely no one would deny that the two hundred million tons of grain that are traded internationally pose far greater dangers than the shipment of small quantities of seed that have been inspected carefully, disinfected and/or fumigated with the best processes now available. Again, *status quo* is comfortable. Unfortunately, the many scientists who have become infected with this timidity virus and are reluctant to speak out against obsolete rules and regulations are increasing the dangers for failure of our crop production system.

Getting Agriculture Moving

To achieve the agricultural productivity gains needed in low-income, food deficit countries to keep pace with rising consumer demand, a combination of factors constraining yield must be manipulated and overcome in an efficient and orchestrated manner. These include: 1) restoration and management of soil fertility, 2) development and use of improved crop varieties (and animal breeds) combining higher genetic yield potential with improved disease and insect resistance, and 3) improved crop management practices including integrated pest management and soil fertility and moisture management programs.

Given current scientific knowledge, it is my belief that agricultural chemicals — especially fertilizers — are absolutely essential to produce the food needed to feed today's population of 5.7 billion, which is increasing currently at the rate of nearly 100 million per year. The amount of organic fertilizers available and crop rotations employing legumes can not alone — without the use of chemical fertilizers — restore and maintain soil fertility to a level adequate to meet the current and rapidly growing food production requirements. The population monster does not allow us to turn back the clock to the "good old days" of the early 1930s, when few agricultural chemicals and little chemical fertilizer were used. Lest I be misunderstood, I want to stress that agricultural chemicals and fertilizers, like medicine, should be used with the proper caution. Clearly, the maintenance of soil fertility becomes more complicated as crop production is intensified. In the future, farmers will have to become more skilled in

soil chemistry and agronomy if they are to deal with the growing secondary and micro-nutrient deficiencies which must be corrected to sustain high grain yields.

The technology that has greatly changed the world food production over the last 50 years, and enabled food production to stay abreast and increase slightly faster than world population, involves the use of improved high yielding crop varieties and proper seed rates and dates of planting, land leveling, fertilization to restore depleted nutrients, and control of disease and insects and weeds. The so-called broadly-adapted, high yielding varieties of wheat and rice that were introduced into Asia during the 1960s, and which produced dramatic results, were not an elixir in themselves. They do not have ability to produce high yields on worn out soils without restoration of the nutrient balance by the proper use of fertilizer to meet the nutrition needs of the plant.

Yet, despite the enormous benefits that chemical fertilizers have brought to the world — which greatly outweigh any deleterious effects due to overuse — the issue of chemical fertilizer use is still subject to heated, and generally uninformed, debate. The fertilizer use issue was a problem in the 1940s and 1950s in Latin America, especially in Mexico. It was one of the main issues that was passionately debated in India, Pakistan and China during the 1960s and early 1970s and currently, it is one of the issues that is most hotly debated in African countries south of the Sahara. In reality the major culprits in over-use of fertilizer are the profligate agricultural systems used in many countries of the north.

Over the past two decades, the environmental movement which has grown in popularity and power, has done much to further confuse the issues concerning restoration of soil fertility. For example, the "virgin" uncultivated oxisoils of Brazil, Colombia, Venezuela, Peru and parts of Africa, because of heavy leaching over geologic periods of time, these soils are depleted of several essential nutrients for vegetative growth. Thus, Mother Nature is involved as well. Moreover, because of the leaching of calcium and magnesium they are strongly acidic and high in soluble aluminum, which is toxic to the roots of most plant varieties. This is the work of Mother Nature not agricultural man. Humankind certainly is also guilty of depleting plant nutrients. This is why slash and burn shifting

cultivation has been so pervasive until relatively recent times. By opening new land, there was an abundance of nutrients for a few years. But as the nutrients were depleted, and plant competition was increased by aggressive weeds, crop yields dropped precipitously, to a point where it was easier and more economical to open new land and abandon the previous land to fallow for 10-15 years. Only during the past one hundred years, has shifting cultivation given way to continuous cultivation based on the replenishment of soil nutrients increasingly with chemical fertilizers.

I should also point out that the forests of Europe were largely destroyed to provide for the agriculture which fed those nations as they were being urbanized and industrialized. The same is true of the United Nations. The Ohio river valley, for example, which is today one of the most important parts of the US grain belt, was once covered with forests, but was deforested and converted into some of the best agricultural land in the world. Consequently, when we see what is going on in the rain forest and some of the other forests in areas of Latin America and Africa today, Europeans and Americans should not forget their own histories. While I do not condone what is going on there, we need to remember that the problem of soil infertility has been haunting humankind from the beginning of agriculture. As human numbers accelerate, the significance of maintaining soil fertility becomes increasingly crucial, not only for food security but indeed to preserve civilization.

Let me use an outstanding example, the case of one of the first American civilizations, namely the civilization of Teotihuacan which was established apparently about 300 BC and flourished and began to deteriorate in the early part of the eighth century AD, and had collapsed by the end of that century. The civilization of Teotihuacan was built on agriculture. At its peak, the city was estimated to have had a population somewhere between 150,000 and 200,000 people. It was even larger than Caesar's Rome. Why did it collapse? There are many different theories. Some scientists believe that the springs and water table dropped below the levels necessary to support the potable water needs of the city; other blames cataclysmic earthquakes; others blame epidemics of pandemic disease; others the shortage of wood for housing, roofing and for cooking and heating fuel, and others attribute the collapse to conquest by a stronger tribe.

However, it is my contention that Toetihuacan collapsed because of the depletion of plant nutrients. We must remember that this huge city was built without either the benefits of the wheel or an animal beast of burden. If one assumes a population of 150,000 with a diet of 2,350 calories per day, largely from maize and beans, one begins to see the problem of supplying that city with its daily food needs. The requirements for maize alone would have been about 88 tons per day. Expressed in terms of 40 kg sacks that would have to be carried on human backs, some 2,200 sacks per day would be required, or approximately 800,000 sacks per year. At that time, there was no information available to the population about how to restore the fertility to the land and the result the collapse of Teotihuacan. As the soil fertility was depleted, more and more of the food had to be brought from greater distances until finally the system collapsed.

Currently, extremists in the environmentalist movement, who have strong influence over international financial institutions by way of lobbying, have convinced the authorities that there is no need for chemical fertilizer, and that organic fertilizers can meet crop needs for a stable food supply. How far this is from the truth. We cannot produce the food that the world needs with the use of organic fertilizers alone, especially for African countries south of the Sahara where there is very little organic matter available. To preach this recommendation is to condemn these African countries. It is time that the world wakes up to this threat!

A major factor responsible for the high payoffs from past agricultural research investments in the developed market economies has been the success of their technology delivery systems, in which private sector organizations have played a major role in supplying information, inputs and agricultural services to the farmer. In many developing nations, the situation is exactly the opposite. Private sector organizations still play a minimal role in the delivery of improved technology while publicly funded input supply, credit and marketing organizations have not been successful in serving the farmer, especially the small-scale producer. Government planners and policy makers must come to grips with the problems of poorly functioning technology delivery systems; what is the value of research that is not used?

In 1986, I helped initiate several agricultural development projects in a handful of sub-Saharan African countries, in collaboration with the late

Japanese philanthropist, Ryoichi Sasakawa (and now enthusiastically supported by his son, Yohei), and former US President Jimmy Carter. These agricultural assistance programs, called Sasakawa-Global 2000 projects, have met with tremendous success in demonstrating basic improvements in maize, sorghum, and/or wheat production. Most of the components of these technologies had been available for a decade, but were laying around, largely unused, on agricultural experiment stations.

Over the past 10 years, we have worked with some 5,000 extension agents in Ghana, Tanzania, Benin, Togo, northern Nigeria, Ethiopia, and Mozambique and more than 250,000 small-scale farmers. We provide each farmer with the technical backstopping and the needed inputs (on credit) to grow a test plot (0.25 to 0.5 ha in size) employing a simple package of improved technology : the best high-yielding variety available, moderate applications of fertilizer, and improved cultural practices. With yields two to three times greater than those previously obtained with traditional technology, the receptivity and enthusiasm of these small-scale farmers is every bit as great as it was in India and Pakistan, when the Green Revolution was taking off 30 years ago. We are now working closely with national policy makers and international development agencies officials to develop policies to strengthen technology delivery systems to sustain these productivity gains.

Closing Comments

Twenty-five years ago, in my acceptance speech for the 1970 Nobel Peace Prize, I said that the Green Revolution had won a temporary success in man's war against hunger, which if fully implemented, could provide sufficient food for humankind through the end of the 20th century. But I warned that unless the frightening power of human reproduction was curbed, the success of the Green Revolution would only be ephemeral. I believe that agricultural scientists have a moral obligation to warn the political, educational, and religious leaders of the world about the magnitude and seriousness of the arable land, food and population problems that lie ahead. If we fail to do so in a forthright manner, we will be negligent in our duty and inadvertently will be contributing to the pending chaos of incalculable millions of deaths by starvation. The

problem will not vanish automatically; to continue to ignore it will make a future solution ultimately more difficult to achieve.

Today, the graduating students will pass from these halls of knowledge and learning into a new life, one hopefully that will be marked by achievement and happiness. I hope all of you will experience the loves of learning and work that I have been privileged to know. Remember, learning is a life-long pursuit. I urge you to reach for the stars! Though we may never get there, surely we will get a little "star dust" on us if we try. Good luck and Good bless!